Substitute Specification

Exhibit 1

Energy Tile Sets

Background of the Invention

The major source of power in the industrialized world is fossil fuel combustion. The supply of fossil fuels is finite, and furthermore, the burning of fossil fuels is believed to contribute greatly to environmental pollution and global warming. Nuclear power is also used for electricity generation but nuclear power stations are potentially extremely dangerous if the reactors are not closely monitored, and the fission process generates highly dangerous waste. Consequently, a global need to develop new ways of generating power has been recognized.

Consequently renewable energy sources have become the focus of much attention. These renewable sources include wave, wind and solar power. All of these sources of power are effectively infinite. In some countries (such as the UK) the government provides financial incentives to individuals and organizations that use alternative energy sources, farther increasing interest in these technologies. Consumers who are 'environmentally aware' welcome products and services that do not negatively impact the environment.

Domestic and industrial water heating consumes a large amount of power. This is both expensive for the consumer, and, if that energy is derived from fossil fuel combustion or nuclear fission, environmentally damaging. Therefore, a means of water heating powered by a free, alternative energy source is highly desirable.

Solar energy is renewable and its generation causes no environmental damage and can be a significant source of power; a south facing roof on a building in Britain receives about 1000 kWh/m^2 per year. Solar energy may be harnessed in solar thermal systems to heat water directly, or by using photovoltaic cells to generate electricity.

Solar thermal systems typically use solar energy incident on building surfaces to heat water. Existing solar thermal systems are often difficult to integrate with roofs, either during construction of the roof or as an addition to an existing roof. They may require modification to the supporting structure of the roof, or they may not be compatible with conventional roofing tiles. Conventional solar thermal systems may be heavy, making them difficult, or even hazardous, to install on roofs. In some cases, cranes may be required to lift and position solar thermal systems.

Some conventional solar thermal systems take the form of assemblies that are fixed on top of an existing roof. A typical example is the MEGASUN (TM) solar hot water heater, available from Helioakmi Ltd., Nea Zoi, Aspropyrgos, 19300, Attiki, Greece. The MEGASUN heater consists of a water storage tank and a solar energy collector on a support base. Water from the tank is circulated through the solar energy collector, which transfers heat accumulated from the sun to the water. The support base, which is adjusted according to the angle of the roof, is screwed on top of the roof. The storage tank and collector are then assembled on the support base. Such specific installation procedures may necessitate special staff training and tools.

Other known solar thermal systems consist of solar thermal tiles that are designed to replace conventional tiles in the roof. These tiles are transparent to solar radiation. The solar radiation that passes through the tile heats a thermal collector in a space under the tile, within the roof. The tile described in International Patent Application WO-02/31415 comprises a one piece transparent polycarbonate moulding. As the tiles are made of polycarbonate, they are susceptible to damage. They are also different in appearance to conventional tiles. Furthermore, it is often desirable to integrate solar thermal tiles with photovoltaic tiles in order to produce both hot water and electricity from solar energy. A solar thermal tile as described in International Patent

Application WO-02/31415 would have a very different appearance to a photovoltaic tile incorporating a photovoltaic laminate. This causes aesthetic problems and results in a heterogenous overall appearance when these tiles are incorporated into a building surface.

It is an object of the present invention to provide a solution to the above problems.

According to the present invention there is provided a solar thermal tile, the tile comprising a transparent portion for permitting the entry of sunlight into a heating space below the tile, the tile further comprising a chassis, formed separately from the transparent portion, on which the transparent portion is mounted, wherein the chassis comprises at least one protrusion on at least one edge, the protrusion forming an overlapping relationship with a second tile when correctly mounted adjacent thereto. In the context of the present invention, a 'chassis' is a support structure. Preferably, the chassis surrounds at least part of another component.

By providing a chassis, the transparent portion may be supported and protected, facilitating ease of storage, handling and fitting. Furthermore, the chassis may fulfill an aesthetic function. A tile formed entirely of a transparent material, such as glass or polycarbonate, would be less durable in comparison to the present invention. A chassis protects the transparent material, thereby allowing the tiles to be readily stacked for storage and transport.

The protrusion facilitates a good fit between the tiles, helping to maintain building accuracy, and further reinforces the whole roof. By providing a protrusion on the chassis, not the transparent material, the chassis bears any loads or impacts inflicted on the building surface, thus preserving the transparent material. In addition to forming an overlapping relationship, the protrusion can be formed to interlock with the neighbouring tile, further strengthening the overall strength of the set of fitted tiles in the building surface. Furthermore, the overlapping relationship formed between a tile according to the present invention and a neighbouring tile helps ensure

that the roof is weatherproof.

The chassis is preferably made of non-transparent material. By providing a chassis made of non-transparent material, materials that are strong, easily formed and lightweight may be employed. Such materials can provide the support and protection necessary for the transparent portion. Thus, by combining a transparent portion and a non-transparent chassis, the necessity for a transparent portion for solar thermal heating is combined with the advantages of non-transparent materials in terms of durability, ease of manufacture, and ease of integration with existing conventional roofing tiles. The non-transparent material may be metal. The metal may be folded to form the chassis, giving a highly durable and readily manufactured chassis. Alternatively, the non-transparent material may be a plastic, with the concomitant advantage of non-corrosion.

The invention further contemplates providing a set of tiles, incorporating at least one solar thermal tile according to the invention. A solar thermal tile according to the present invention is readily integrated with conventional roofing tiles, and thus may be provided as part of a set of tiles for installation in a building surface. A building surface may be a roof or a wall.

The set of tiles preferably further comprises photovoltaic tiles comprising photovoltaic cells. The photovoltaic tiles may comprise a chassis. The chassis confers similar advantages when provided in combination with a photovoltaic cell as it does when provided in combination with a transparent portion of a solar thermal tile. It would in some circumstances be desirable to integrate solar thermal water heating tiles and photovoltaic tiles in the same building surface, in order to heat water and generate electricity on those building surfaces that receive the most incident sunlight. By providing a building surface incorporating a set of tiles comprising solar thermal tiles and photovoltaic tiles according to an embodiment of the present invention, a

durable and aesthetically uniform building surface that supplies solar thermal energy and solar electricity is obtained.

Further features and advantages of the invention will become apparent from the following description of preferred embodiments of the invention, given by way of example only, which is made with reference to the accompanying drawings.

Brief Description of the Drawings

Figure 1 illustrates a solar thermal tile as an embodiment of the present invention.

Figures 2a, 2b, and 2c illustrate right, left and front end views of the solar thermal tile illustrated in Figure 1.

Figure 3 illustrates the underside of the solar thermal tile illustrated in Figure 1.

Figure 4 illustrates an embodiment of the present invention, incorporated into a building surface.

Figure 5 illustrates the embodiment of the invention of Figure 1 incorporated into a building surface.

Figure 6 illustrates a photovoltaic tile.

Figure 7 illustrates the underside of the photovoltaic tile of Figure 6.

Figure 8 illustrates an embodiment of the invention in combination with a photovoltaic tile, in a building surface.

Figures 9 and 10 illustrate an embodiment of the invention incorporated into a building.

Figure 11 illustrates an alternative embodiment of the invention, in combination with a conventional roofing tile.

Detailed Description of the Drawings

Figure 1 illustrates a solar thermal tile 1 according to a first embodiment

of the invention. The transparent portion 2 consists of a polyoarbonate sheet supported in the chassis 6. Alternatively, the transparent portion may consist of toughened glass. The transparent portion may be affixed to the chassis using a sealant, and/or with tape, bolts, or screws. The chassis 6 is formed of folded sheet metal. The chassis 6 comprises a supporting bar 3 (shown in Figure 2), a rear overlap section 8, a front end 10, and left and right ends 12 and 14, respectively. In an embodiment, the chassis 6 is formed in two parts, the first part consisting substantially of rear overlap section 8, supporting bar 3 and portions of the left end 12 and right end 14, the second part consisting of the rest of the chassis, comprising front end 10, the remainder of left and right ends and 14, and the portion of the chassis that surrounds transparent portion 2. It will be recognised that the chassis could however be formed in one unitary part or it could be made of several individual parts.

The left end 12 has a first protrusion 16 which both co-extends substantially with the left end 12 and protrudes horizontally outwards from the left end 12. The right end 14 has a similar second protrusion 18. The first and second protrusions 16 and 18 form an overlapping relationship with another adjacent tile placed alongside; along the horizontal axis. The adjacent tile may be another solar thermal tile according to an embodiment of the invention, or a conventional roofing tile, a photovoltaic tile or another form of building surface.

In an embodiment, the chassis is formed of folded sheet metal. The chassis may be formed from several individually formed folded sheet metal sections, which are bonded together by welding and/or riveting. The chassis may be powder-coated, galvanised, painted, or plastic coated in order to prevent corrosion. In a specific embodiment, the chassis is formed from several sections of folded steel, TIG (tungsten inert gas) welded and pop-riveted together. The assembled chassis is powder coated.

Figure 2a shows the right end (profile) view of the solar thermal tile 1,showing right end 14. Second protrusion 18 can be seen coextending along right end 14 and incorporates a downturned edge which forms an overlapping relationship with a neighbouring tile.

Figure 2b shows the left end (profile) view of the solar thermal tile 1, showing left end 12. The first protrusion 16 extends from the left end 12. First protrusion 16 incorporates an upturned edge and forms an overlapping relationship with a neighbouring tile. The formation of the protrusion may be altered according to the form of a neighbouring tile.

In another embodiment, the protrusion may be formed so as to interlock with a neighbouring tile. For example, the edges could be extended so as to make physical contact with a neighbouring tile.

Figure 2c shows the front view of the solar thermal tile 1..The front end and the supporting bar 3 can be seen. The first and second protrusions 16 and 18 can be seen extending horizontally from right and left ends 12 and 14 respectively. When two solar thermal tiles 1 are placed correctly adjacent with respect to one another, the first protrusion 16 of a first tile would form an overlapping relationship with the second protrusion 18 of a second tile. The overlapping relationship of the first and second protrusions 16 and 18 forms a robust, accurate, space efficient and weatherproof interconnection between the two tiles.

Figure 3 shows a bottom view of the tile of Figures 1, 2a, 2b and 2c. Right end 14 and front end 10 are indicated for the purposes of orientation. The underside of chassis 6 incorporates apertures 30, 31, 32 and 33. The apertures transmit solar radiation that has passed through the transparent portion 2 (shown in Figure 1) from the tile to the heating space below the tile.

Figure 4 illustrates the incorporation of a tile into a building surface according to an embodiment of the invention. Figure 4 shows a profile view of solar thermal tile 1 incorporated

into a roof between conventional tiles 20 and 22, the roof having an apex 24. The solar thermal tile 1 is supported on a first batten 34A by the supporting bar 3. The solar thermal tile 1 is further supported by overlapping with conventional tile 22. The first and second battens 34A and 34B are horizontal wooden battens, as found in many conventional roofs. The chassis 6 and supporting bar 3 are provided with holes, in order to secure the tile to the batten with screws or bolts.

Beneath solar thermal tile 1 is a heating space 35. The heating space 35 is enclosed within container 39 to prevent convective heat loss. Container 39 is supported between battens 34A and 34B. The heating space 35 includes a heating surface 36. The heating surface 36 is made up of two sheets of conductive material, such as a metal. The heating surface may be treated in a number of ways in order to maximise its absorption in the solar spectrum while minimising its heat emission characteristics in the infra-red region of the spectrum. In this embodiment, heating surface 36 is painted black for maximum absorption. The heating surface 36 is in conductive communication with a pipe 37 that contains water. The pipe 37 is made of a thermally conductive material such as copper. Container 39 comprises a layer of insulation 38. The container 39 is ideally airtight in order to prevent loss of heat by convection, and to maintain a heated air environment around the heating surface 36 and the pipe 37.

In this embodiment of the invention, sunlight passes through transparent portion 2 of solar thermal tile 1, then through apertures 30, 31, 32 and 33 (shown in Figure 3) to heating space 35. In heating space 35, the sunlight is absorbed by heating surface 36. Heating surface 36 conducts heat energy to pipe 37, where the heat energy is absorbed by the water within the pipe. The heated water is then pumped away actively or passively for domestic use. Insulating layer 38 ensures that the temperature of heating space 35 is maximised by preventing loss of heat energy.

Loss of heat energy by convection is further minimised by the insulative blanket of still air around heating surface 36 and pipe 37. The transparent portion 2 may be double glazed (including more than one transparent sheet) to further reduce heat loss.

The rear overlap section 8 of the chassis of solar thermal tile 1 is formed to accommodate another tile in the vertical axis. When solar thermal tile 1 is incorporated into a building surface such as a roof, tiles placed above solar thermal tile 1 overlay the rear overlap section 8. The conventional roofing tile 20 overlaps the solar thermal tile 1 at the rear overlap section 8, while the solar 20 thermal tile 1 itself overlaps conventional roofing file 22. Rain will flow away from the roof apex 24 down the tiles and due to the arrangement of the overlapping of the conventional tile solar thermal tile 1 and conventional tile 22 will be prevented from leaking through the roof.

Figure 5 illustrates solar thermal tile 1 integrated into a building surface 60. Dashed lines indicate features that would not be visible, such as protrusions or the edges of tiles that are concealed by other overlapping tiles. Solar thermal tile 1 is shown to scale with the building surface 60 ~~which~~ that consists of three horizontal rows of overlapping tiles.

The building surface 60 may form part of a roof or a wall. The building surface 60 includes conventional tiles 50-59 and solar thermal tile 1. Dashed lines indicate features that are in practice hidden from view behind other features. Protrusions 16 and 18 form overlapping relationships with cooperating formations on neighbouring conventional tiles 54 and 55 at edges 62 and 64. It can be seen that in the vertical axis, the edges of conventional tiles 50-53 overlap solar thermal tile 1 and solar thermal tile 1 overlaps part of conventional tiles 56, 57, 58 and 59 in order to create a waterproof sloping 55 building surface of uniform appearance. Solar thermal tile 1 is equivalent in width to four conventional tiles and in length is equivalent to one

conventional tile, in order to fit into the building surface without the need for specially sized surrounding tiles.

Figure 6 shows a photovoltaic file 90 according to an embodiment of the invention. Photovoltaic tile 90 incorporates a chassis 92, a photovoltaic laminate 94 and protrusions 96 and 98. The photovoltaic laminate 94 is made up of protective layers and photovoltaic cells (not shown) and generates electricity from incident solar light.

The chassis 92 is formed of folded sheet metal and includes a front end 91 and a rear overlay section 95. In this embodiment of the invention, chassis 92 is similar in appearance and construction to chassis 6 of Figure 1. In this way, a homogenous and uniform appearance will be achieved when photovoltaic tile 90 and solar thermal tile 1 are incorporated into the same building surface. The provision of a chassis confers similar advantages for a photovoltaic file as for a solar thermal tile, such as lightness, durability, mechanical strength, ease of handling and fitment, ease of manufacture and ease of integration with existing conventional roofing tiles. However, that front end 91 includes ventilation holes to allow airflow into the tile and prevent overheating of the photovoltaic cells within the tile. The ventilation holes are not present in the solar thermal tile chassis.

Figure 7 shows the underside of photovoltaic tile 90, showing apertures 110, 111, 112 and 113. Front end 91 is shown for the purposes of orientation. Photovoltaic cells within chassis 92 are connected to power outlet 115. Power outlet 115 is connected to power lines 116 and 118. Power lines 116 and 118 end in plugs 120 and 122 respectively. Plugs 120 and 122 may be connected to an electrical network in order to supply electricity to the network or to a neighbouring photovoltaic cell in order to provide an array of photovoltaic tiles; the array being connected as a whole to an electrical network.

Figure 8 shows an embodiment of the invention in combination with photovoltaic tile 90. Building surface 70 comprises three horizontal rows of tiles and incorporates a solar thermal tile 1 according to an embodiment of the present invention and the photovoltaic tile 90. As in Figure 5, dashed lines indicate features that would not be visible in practice, such as the edges of tiles and protrusions that are underneath other tiles. The first and second protrusions 16 and 18 of solar thermal tile 1 form overlapping relationships with neighbouring conventional tiles 101 and 102 respectively. Protrusions 96 and 98 of photovoltaic tile 90 form overlapping relationships with neighbouring conventional tiles 103 and 104. It can be seen that solar thermal tile 1 and photovoltaic tile 90 are overlapped by conventional building tiles above them and solar thermal tile 1 and photovoltaic tile 90 themselves overlap a layer of conventional tiles below them. Building surface 70 provides both solar thermal water heating and solar-generated electricity.

Figure 9 shows an embodiment of the invention, incorporated into a surface of a building. Building 140 has a roof 142, the roof including conventional tiles in area 144, an area of solar thermal tiles 200 comprising solar thermal tiles according to an embodiment of the present invention, and an area of photovoltaic tiles 202 comprising photovoltaic tiles according to an aspect of the present invention. Building 140 has a plumbing system (shown in Figure 10) that allows the solar thermal system to add heat to the domestic hot water system in the building.

With respect to the placing of the area of solar thermal tiles 200 and the area of photovoltaic tiles 202 on building 140, non-tracking (stationary) solar thermal and photovoltaic systems on buildings in the northern hemisphere should be placed on a surface that faces true south. The systems should be placed at an angle equal to the latitude of the geographical area of the building in order to ensure maximum incident sunlight. The surface should not be shaded. The building may include a battery system (not shown) to store the electricity produced by

photovoltaic tiles.

Figure 10 shows part of the plumbing system of building 140 shown in Figure 9. Figure 10 illustrates a portion of the inside surface of the roof 142 where the area of solar thermal tiles 200 and the area of photovoltaic tiles 202 meet. The roof 142 is of a known type, consisting of a timber framework overlaid with tiles and incorporates vertical joists 150 and horizontal battens 160 on which all tiles are placed and to which all tiles are secured.

Solar thermal tile 146 according to an embodiment of the invention and photovoltaic file 148 are shown. Solar thermal tile 146 and photovoltaic tile 148 are secured to the batten 162 by supporting bars 152 and 154 respectively. Photovoltaic tile 148 includes apertures 156, 157 and 158 and electricity generated by the photovoltaic cells within the photovoltaic tile 148 is provided to an electrical network via electrical cable 164. Solar thermal tile 146 has a heating space 166. In an embodiment of the invention the heating space 166 is arranged similarly to the heating space 35, as shown in Figure 4. Cold water is pumped into heating space 166 via inlet pipe 168 and out via outlet pipe 170. In this way, the plumbing system of the building is connected to the fluid heating system of the tile.

Figure 11 illustrates an alternative embodiment of the invention in combination with a conventional tile. The 'Galloway' tile (available from Russell Roof Tiles, Wellington Road, Burton-on-Trent, Staffs DE14 2AW, UK) is an example of a conventional tile. A cross section is shown. A solar thermal tile 180 according to an embodiment of the invention has a protrusion 182. The conventional tile 186 has a corrugated edge 188. It can be seen that in addition to forming an overlapping relationship in accordance with the invention, the protrusion 182 and corrugated edges 188 of the protrusions can form a firm, robust interlock. Alteration of the dimensions of the protrusion 182 and corrugated edge 188 will allow physical contact, further

strengthening the 30 interconnection between solar thermal tile 180 and conventional tile 186.

In an embodiment of the invention, the heating space may contain a heat collecting assembly. In an embodiment, this assembly may take the form of an array of tubes containing a heating medium. The tubes of the assembly may be formed of a metal such as copper, which is easily worked into complex tubular shapes and is highly conductive.

The heating medium may be a liquid such as water that may be used directly for domestic hot water applications. Alternatively oil may be used, in which case the heat would need to be transferred from the oil to water.

The shape of the protrusion may be altered. For example, the protrusion may be corrugated to match the corrugation of a neighbouring conventional roof tile.

In an embodiment where the heat collecting assembly contains a liquid heating medium, the assembly is arranged to be in fluid communication with the outside of the tile, so that a heating medium may be pumped in and out of the tile. In an alternative embodiment, the heat collecting assembly may take the form of a grid made up of solid metal wire in conductive communication with the outside of the tile. The space occupied by the heating assembly may be lined with a reflective material such as metal foil, in order to reflect radiation from the heat collecting assembly back towards it. Alternatively, thermal insulation such as rock wool or fibreglass may be used in the heating space.

Due to the temperature difference between the heating space and the air outside the building surface, condensation may form in the heating space. The chassis may incorporate air holes to prevent the accumulation of moisture within the tile.

A tile according to the present invention may be used in a wide variety of climates and may be adapted for differing environments. For example, in coastal regions the chassis may be

made of anodised aluminium to prevent corrosion caused by humidity and salt water. The chassis may be made with an inwardly reflective coating in order to prevent any heat loss from the heating space.

The transparent portion may be a sheet made of polycarbonate or alternative materials, such as laminated glass. Glass and steel have similar thermal expansion characteristics. An advantage of such a combination is that in high temperatures, the structure of the tile as a whole will not be compromised as the transparent portion and the chassis will expand at approximately the same rate.

An embodiment of the invention may be implemented in a variety of locations. An embodiment of the invention may be implemented in both permanent and temporary buildings, during or after construction.